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QUALITY CONTROL OF
METEOROLOGICAL OBSERVATIONS

by

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Technical Report for Period

January 1991-June 1991

Approved for public release; distribution unlimited

Prepared for: Naval Oceanographic and Atmospheric
Research Laboratory, Atmospheric
Directorate
Monterey, CA 93943

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REPORT DOCUMENTATION PAGE				Form Approved OMB No 0704-0188	
1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b RESTRICTIVE MARKINGS		
2a SECURITY CLASSIFICATION AUTHORITY			3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited		
2b DECLASSIFICATION/DOWNGRADING SCHEDULE					
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPS-53-91-013			5 MONITORING ORGANIZATION REPORT NUMBER(S)		
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School		6b OFFICE SYMBOL (If applicable) MA	7a NAME OF MONITORING ORGANIZATION Naval Oceanographic and Atmos- pheric Research Lab., Atmos. Dir.		
6c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943			7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943		
8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Ocean. & Atmos. Research Lab., Atmos. Dir.		8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 0602435N		
8c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943			10 SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO	PROJECT NO	TASK NO
11 TITLE (Include Security Classification) Quality Control of Meteorological Observations (U)					
12 PERSONAL AUTHOR(S) Toke Jayachandran and Richard Franke					
13a TYPE OF REPORT Technical Report		13b TIME COVERED FROM 01/91 TO 06/91		14 DATE OF REPORT (Year, Month, Day) 16 September 1991	
15 PAGE COUNT 19					
16 SUPPLEMENTARY NOTATION					
17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	radiosonde data, meteorological data, outliers observation increments, error bias, quality control		
19 ABSTRACT (Continue on reverse if necessary and identify by block number) A test for outliers is discussed and a computer program for its application to meteorological data for purposes of quality control is given. The data for the examples is from the NOARL database of observation minus forecast increments. The program will tag outliers from a group of stations based on daily values over a period of time, mean values over that time period, and standard deviations over that time period.					
20 DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a NAME OF RESPONSIBLE INDIVIDUAL Toke Jayachandran			22b TELEPHONE (Include Area Code) 408-646-2600		22c OFFICE SYMBOL MA/JY

QUALITY CONTROL OF METEOROLOGICAL OBSERVATIONS

Toke Jayachandran and Richard Franke

Introduction: A major input component to weather prediction systems is the observational data, typically geopotential heights and winds from weather observing stations around the world. The Navy Operational Global Atmospheric Prediction System (NOGAPS) produces weather forecasts using a spectral forecast model. Preceding the forecast is a multivariate objective analysis, followed by a nonlinear normal mode initialization scheme. The multivariate objective analysis scheme uses the weather observations to produce analyzed fields with minimum statistical error. As is to be expected, some of the observations will turn out to be erroneous for various reasons such as the mis-calibration of the measurement devices, failure to perform prescribed data corrections, communications errors and simple recording errors. We present in this paper a quality control methodology to screen the data to identify those observations that appear to be erroneous in a statistical sense. It is then up to a meteorological analyst or a decision making algorithm to examine the tagged observations and decide on a course of action - delete the miscreant observations, modify the data if appropriate or include the observations, as is, for NOGAPS analysis. The procedures can also be used to monitor the reliability of the observing stations and to alert them of any mispractices.

Data Quality Tests: The methodology proposed here is an adaptation of a statistical test for outliers (Dixon, 1950 [1]). The first step in the application of this test is to partition the monitoring stations into small "contiguous groups". The recorded observations within any single group are expected to be "similar" because the weather patterns at these monitoring sites are comparable due to the proximity of the stations to each other.

One approach towards identifying such a group of stations is the following. Select the latitude and longitude for a target location on the surface of the earth (this could be the coordinates of a reporting station of interest) and choose an approximately square region by specifying a range for the latitude, say 5° above and below the target, and within a similar distance in the longitudinal direction. The observational increments (differences between the reported measurements and the forecast values) for all of the stations within the designated area are then subjected to a sequence of outlier tests.

Assume that the number of reporting stations within the target area is N and the data from the most recent k days (say 30 days) is to be examined for quality. Let $X_{i1}, X_{i2}, \dots, X_{ik}$ be the observation increments for the i^{th} station, $i = 1, 2, \dots, N$; let M_1, M_2, \dots, M_N be the means of the increments (averaged over the k days for each of the N stations) and S_1, S_2, \dots, S_N the standard deviations (over the k days) for the N stations.

The first test we propose is to compare the daily observational increments $X_{1j}, X_{2j}, \dots, X_{Nj}$ for the j^{th} day, and check for "outliers". Let $Y_1 < Y_2 < \dots < Y_N$ be the data rearranged in increasing order. Compute

$$r_{11} = (Y_N - Y_{N-1}) / (Y_N - Y_2) ;$$

if r_{11} exceeds the tabulated value in Table A (extracted from Dixon, 1950), corresponding to a chosen statistical significance level β (say .05), conclude that the observed datum for the station corresponding to Y_N is an outlier. This implies that the

observation increment Y_N is too large relative to the increments for the other stations in the region. That is, the observed geopotential height appears to be too high (large) when compared to the forecast. Now compute

$$r'_{11} = (Y_2 - Y_1) / (Y_{N-1} - Y_1)$$

and conclude that Y_1 is an outlier if r'_{11} exceeds the tabulated value in Table A; if this happens, the implication is that the observed geopotential height is too low (small) compared to the forecast. These tests can be performed for each of the days for which data is available. The meteorological analyst or the decision making algorithm will then have to choose a course of action, based on some established decision rule, for each of the observations failing the test. The two tests were applied to actual data from three different areas of the globe viz., US, Europe, and China. In each area we identified a location by specifying its latitude and longitude and then selected all the stations within 4° of this location. The results of the daily tests are presented in Tables 1a,b,c. The I.D. numbers of the stations included for the test are listed in the first column. The entries (there are two entries in each of the 16 columns) in the table represent the number of days in October '90 on which the stations failed the outlier test at the low end (r_{11}' test) and the test at the high end (r_{11} test) using the data (geopotential height differences) for 16 pressure levels (1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 15, 10 mb). A dot in any position implies no failures; an asterisk indicates insufficient data to perform the tests. Such a table can be used in making quality judgments on the performance of the monitoring stations.

Another test that can also be used to monitor the performance

quality of weather stations is to perform the two outlier tests on the averages M_1 , M_2 , . . . , M_N . The data for the tests are these averages rearranged in increasing order. Tables 2a,b,c present the same type of information as Tables 1a,b,c except that this time the entries are a 1 or a dot; a 1 signifies that the average for a station failed the outlier test while a dot would signify that the station passed the test.

A third outlier test, that can be viewed as a test for consistency, is to check for an outlier in the station standard deviations S_1 , S_2 , . . . , S_N . If $Y_1 < Y_2 < . . . < Y_N$ are these standard deviations in ordered form, compute

$$r_{10} = (Y_N - Y_{N-1}) / (Y_N - Y_1)$$

and conclude that the standard deviation corresponding to Y_N is statistically too large relative to the others, if r_{10} exceeds the critical value in Table B (extracted from Dixon, 1950) at a significance level β (say .05). Tables 3a,b,c are similar to Tables 1 and 2 using the station standard deviations, with the difference that only the high end outlier test is used.

We have written a computer program, using Fortran, that will select (1) the reporting stations within a specified (approximately square) region around a specified location and (2) the appropriate data for these stations from the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) files [2], and automatically performs all of the tests described above. Tables 1, 2 and 3, described above, are the actual outputs of this program. The program also generates additional information such as the number of times the daily outlier tests were performed (Table 4) and the number of days for which data was available (Table 5), during the period specified for the test. The numbers

in Table 4 will sometimes be smaller than the corresponding entries in Table 5; this happens whenever the number of data points available for the test is smaller than the minimum sample size of 4. Table 6 is an example of another type of output of the program; for a selected station the table provides the daily test history, over the 16 pressure levels. A "PASS" indicates that the station passed all the daily tests; a "LFAIL" signifies that the observational increment is too low as compared to the numbers for the other stations in the region, on at least one day of the testing period. A "FAILH" denotes that the increment for at least one day was deemed to be high. Similar tables displaying the results of the means and standard deviations tests are also produced. In the "TOTAL" column a "PASS" means that the station passed all the tests on all the days and a "FAIL" implies the converse.

References

- [1] Dixon, W.J., "Ratios Involving Extreme Values", Annals of Mathematical Statistics, Vol.22, No.1, March 1951.

- [2] Baker, Nancy L., "The Adaptive Quality Control and Analysis Statistical Database", NOARL Technical Note, May 29, 1991, Naval Oceanographic and Atmospheric Research Laboratory, Stennis Space Center, Bay St Louis, Miss 39529.

TABLE A

n	α	.005	.01	.02	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	α	n
3	4	.994	.988	.976	.941	.886	.781	.684	.591	.500	.409	.316	.219	.114	.059	3
4	5	.926	.889	.846	.765	.679	.560	.471	.394	.324	.257	.193	.130	.063	.033	4
5	6	.821	.780	.729	.642	.557	.451	.373	.308	.250	.196	.146	.097	.045	.023	5
6	7	.740	.698	.644	.560	.482	.396	.318	.261	.210	.164	.121	.079	.038	.018	6
7	8	.680	.637	.586	.507	.434	.344	.281	.230	.184	.143	.105	.068	.032	.016	7
8	9	.634	.590	.543	.468	.399	.314	.253	.208	.166	.128	.094	.060	.029	.014	8
9	10	.596	.555	.510	.437	.370	.290	.234	.191	.152	.118	.086	.055	.026	.013	9
10	11	.568	.527	.483	.412	.349	.273	.219	.178	.142	.110	.080	.051	.025	.012	10
11	12	.542	.502	.460	.392	.332	.259	.206	.168	.133	.103	.074	.048	.023	.011	11
12	13	.522	.482	.441	.376	.318	.247	.197	.160	.126	.097	.070	.045	.022	.011	12
13	14	.503	.463	.425	.361	.305	.237	.188	.153	.120	.092	.067	.043	.021	.010	13
14	15	.488	.450	.411	.349	.294	.228	.181	.147	.115	.088	.064	.041	.020	.010	14
15	16	.475	.438	.399	.338	.285	.220	.175	.141	.111	.085	.062	.040	.019	.010	15
16	17	.463	.426	.388	.329	.277	.213	.169	.136	.107	.082	.060	.039	.019	.009	16
17	18	.452	.416	.379	.320	.269	.207	.165	.132	.104	.080	.058	.038	.018	.009	17
18	19	.442	.407	.370	.313	.263	.202	.160	.129	.101	.078	.056	.036	.015	.009	18
19	20	.433	.398	.363	.306	.258	.197	.157	.125	.098	.076	.055	.036	.017	.008	19
20	21	.425	.391	.356	.300	.252	.193	.153	.122	.096	.074	.053	.035	.017	.008	20
21	22	.418	.384	.350	.295	.247	.189	.150	.119	.094	.072	.052	.034	.016	.008	21
22	23	.411	.378	.344	.290	.242	.185	.147	.117	.092	.071	.051	.033	.016	.008	22
23	24	.404	.372	.338	.285	.238	.182	.144	.115	.090	.069	.050	.033	.016	.008	23
24	25	.399	.367	.333	.281	.234	.179	.142	.113	.089	.068	.049	.032	.016	.008	24
25	26	.393	.362	.329	.277	.230	.176	.139	.111	.088	.067	.048	.032	.015	.008	25
26	27	.388	.357	.324	.273	.227	.173	.137	.109	.086	.066	.047	.031	.015	.007	26
27	28	.384	.353	.320	.269	.224	.171	.135	.108	.085	.065	.047	.031	.015	.007	27
28	29	.380	.349	.316	.266	.220	.168	.133	.106	.084	.064	.046	.030	.015	.007	28
29	30	.376	.345	.312	.263	.218	.166	.131	.105	.083	.063	.046	.030	.014	.007	29
30		.372	.341	.309	.260	.215	.164	.130	.103	.082	.062	.045	.029	.014	.007	30

TABLE B

n	α	.005	.01	.02	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95	α	n
4	5	.995	.991	.981	.955	.910	.822	.737	.648	.554	.459	.362	.250	.131	.069	4	4
5	6	.937	.916	.876	.807	.728	.615	.524	.444	.369	.296	.224	.151	.078	.039	5	5
6	7	.839	.805	.763	.689	.609	.502	.420	.350	.288	.227	.169	.113	.056	.025	6	6
7	8	.782	.740	.689	.610	.530	.432	.359	.298	.241	.189	.140	.093	.045	.022	7	7
8	9	.725	.683	.631	.554	.479	.385	.318	.260	.210	.164	.121	.079	.037	.019	8	8
9	10	.677	.635	.587	.512	.441	.352	.288	.236	.189	.148	.107	.070	.033	.016	9	9
10	11	.639	.597	.551	.477	.409	.325	.265	.216	.173	.134	.098	.063	.030	.014	10	10
11	12	.606	.566	.521	.450	.385	.305	.248	.202	.161	.124	.090	.058	.028	.013	11	11
12	13	.580	.541	.498	.428	.367	.289	.234	.190	.150	.116	.084	.055	.026	.012	12	12
13	14	.558	.520	.477	.410	.350	.275	.222	.180	.142	.109	.079	.052	.025	.012	13	13
14	15	.539	.502	.460	.395	.336	.264	.212	.171	.135	.104	.075	.049	.024	.011	14	14
15	16	.522	.486	.445	.381	.323	.253	.203	.164	.129	.099	.072	.047	.023	.011	15	15
16	17	.508	.472	.432	.369	.313	.244	.196	.158	.124	.095	.069	.045	.022	.011	16	16
17	18	.495	.460	.420	.359	.303	.236	.190	.152	.119	.092	.067	.044	.021	.010	17	17
18	19	.484	.449	.410	.349	.295	.229	.184	.148	.116	.089	.065	.042	.020	.010	18	18
19	20	.473	.439	.400	.341	.288	.223	.179	.143	.112	.087	.063	.041	.020	.010	19	19
20	21	.464	.430	.392	.334	.282	.218	.174	.139	.110	.084	.061	.040	.019	.010	20	20
21	22	.455	.421	.384	.327	.276	.213	.170	.136	.107	.082	.059	.039	.019	.009	21	21
22	23	.446	.414	.377	.320	.270	.208	.166	.132	.104	.081	.058	.038	.018	.009	22	22
23	24	.439	.407	.371	.314	.265	.204	.163	.130	.102	.079	.056	.037	.018	.009	23	23
24	25	.432	.400	.365	.309	.260	.200	.160	.127	.100	.077	.055	.036	.018	.009	24	24
25	26	.426	.394	.359	.304	.255	.197	.156	.124	.098	.076	.054	.036	.017	.009	25	25
26	27	.420	.389	.354	.299	.250	.193	.154	.122	.096	.074	.053	.035	.017	.008	26	26
27	28	.414	.383	.349	.295	.246	.190	.151	.120	.095	.073	.052	.034	.017	.008	27	27
28	29	.409	.378	.344	.291	.243	.188	.149	.118	.093	.072	.051	.034	.016	.008	28	28
29	30	.404	.374	.340	.287	.239	.185	.146	.116	.092	.070	.051	.033	.016	.008	29	29
30		.399	.369	.336	.283	.236	.182	.144	.115	.090	.069	.050	.032	.016	.008	30	30

Extracted from: "Ratios of Extrema Values", W. J. Dixon, Annals of Mathematical Statistics. Vol. 22, No. 1, March, 1951.

STATION /	Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16																
72456		2	.	.	1	.	1	.	1	1	3	.	.	.	2	.	.	.	2	.	.	1	1	2	*	*	
72357		.	.	2	.	5	.	2	.	1	.	1	.	2	.	1	.	1	.	1	.	2	.	.	.	2	.	1	.	1	.	*	*
72349		.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*
72340		*	*
72260		.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*
72247		1	.	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	2	*	*
72239		1	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
72257		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 1a: Failures in daily outlier test (. = 0, * = no test)
U.S. stations near (35° , -95°)
10/01/90 to 10/31/90 at 00Z

STATION /	Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
26702		. 1	. 1	. 1	. 3	. 1	. .	. .	. .	. .	. 1	. 1	. 1	. 1	. 2	. 1	. .
26406		1 .	1 .	2 .	1 .	1 .	1 .	. 3	. .	. 1	. .	. .	. .	. .	. .	. .	1 .
12425		. .	1 .	. 1	. .	. .	. .	1 .	. 1	. .	. .	. 1	. 2	1 2	1 1	. .	. .
12374	 1	. 1	. .	. .	1 .	1 .	1 .	1 .	. .	2 .	2 .	1 .	. .
12330		. .	1 1	. .	. .	1 .	. .	. .	. .	. .	1 .	. .	. .	1 .	1 .	. .	. .
12120		1 .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10437		. 1	. 1	. .	. .	. 1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10338	
10046		1 .	1 .	2 .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10035	
9393	 1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. 1	. .
9184		1 .	. .	1 .	. .	. .	. .	. .	. .
6181	
2591	 1	. 2	. 1	. 1	. .	. .	. .	. .	. .	. .	. .	. .
2527	 1	. 1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .

Table 1b: Failures in daily outlier test (. = 0, * = no test)
European stations near (55° , 15°)
10/01/90 to 10/31/90 at 00Z

STATION /	Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
57679	1	1	.	1	.	2

Table 1c: Failures in daily outlier test (. = 0, * = no test)
Chinese stations near (32° , 110°)
10/01/90 to 10/31/90 at 12Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72456
72357	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.
72349
72340
72260
72247	1	1
72239	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
72257	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 2a: Failures in the means test (. = 0, * = no test)
U.S. stations near (35° , -95°)
10/01/90 to 10/31/90 at 00Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
26702
26406
12425
12374	*
12330	*	*
12120	*	*	*
10437	*	*	*	*	*
10338	*	*	*	*	*
10046	*	*	*	*	*
10035
9393
9184
6181
2591	*	*
2527	*	*

Table 2b: Failures in the means test (. = 0, * = no test)
European stations near (55° , 15°)
10/01/90 to 10/31/90 at 00Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
57679	*
57516	*	*	.	1	.	.	.	.	.	.	1	.	.	.	1	.
57494
57461	.	.	*	*	*
57447	.	.	*	*	*
57328	*	*	*	*	1	.	*	*	*	*	*	*
57178	.	.	*	*	*
57127
57083	*
57036	*
57245	*	*	*	*	*	*	*	*	*
57633	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 2c: Failures in the means test (. = 0, * = no test)
Chinese stations near (32° , 110°)
10/01/90 to 10/31/90 at 00Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72456
72357
72349
72340
72260
72247	1	.	.	.	1	1	.
72239	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
72257	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 3a: Failures in the standard deviations test (. = 0, * = no test)
U.S. stations near (35° , -95°)
10/01/90 to 10/31/90 at 00Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
26702
26406
12425	1	.	.	.
12374	*
12330	.	1	.	.	.	.	.	.	.	.	.	.	.	.	*	*
12120	*	*	*
10437	*	*	*	*	*
10338
10046	*	*	*	*	*
10035
9393
9184
6181
2591	*	*
2527	*	*

Table 3b: Failures in the standard deviations test (. = 0, * = no test)
European stations near (55° , 15°)
10/01/90 to 10/31/90 at 00Z

STATION / Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
57679	*
57516	*
57494
57461	.	*	*
57447	.	*
57328	*	*	*	*	*	*	*	*	*	*	*
57178	.	*	*
57127
57083	*
57036	*
57245	*	*	*	*	*	*	*
57633	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 3c: Failures in the standard deviations test (. = 0, * = no test)
Chinese stations near (32° , 110°)
10/01/90 to 10/31/90 at 00Z

STATION /	Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72456	31	30	31	31	31	31	31	31	31	31	31	30	29	27	24	23	0
72357	31	30	31	31	31	31	30	31	31	31	30	30	30	29	26	22	0
72349	31	30	31	31	30	31	30	30	30	30	30	30	29	28	28	22	0
72340	31	29	31	31	30	30	30	30	30	30	30	29	28	28	26	22	0
72260	30	29	30	30	30	30	30	29	29	29	29	29	29	28	26	23	0
72247	31	28	31	31	31	31	31	31	31	31	31	29	29	29	27	23	0
72239	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
72257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4: Number of days daily outlier test was performed
U.S. stations near (35° , -95°)
10/01/90 to 10/31/90 at 00Z

STATION /	Lvl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72456	31	30	31	31	31	31	31	31	31	31	31	30	29	28	25	24	11
72357	31	30	31	31	31	30	31	31	31	31	30	30	30	30	28	25	4
72349	31	30	31	31	30	31	30	30	30	30	30	30	29	28	28	23	6
72340	31	29	31	31	30	30	30	30	30	30	30	29	28	28	27	24	2
72260	30	29	30	30	30	30	30	29	29	29	29	29	29	29	28	27	3
72247	31	28	31	31	31	31	31	31	31	31	31	29	29	29	27	23	6
72239	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
72257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Number of daily reports
U.S. stations near (35° , -95°)
10/01/90 to 10/31/90 at 00Z

STATION 72456: LAT,LON = 39, -95

LEVEL	#DAYS	DAILY TESTS		MEANS TESTS		STD TESTS	TOTAL
1	31	PASS	PASS	PASS	PASS	PASS	PASS
2	30	PASS	PASS	PASS	PASS	PASS	PASS
3	31	PASS	PASS	PASS	PASS	PASS	PASS
4	31	PASS	*FAILH	PASS	PASS	PASS	*FAIL*
5	31	PASS	PASS	PASS	PASS	PASS	PASS
6	31	LFAIL*	PASS	PASS	PASS	PASS	*FAIL*
7	31	LFAIL*	PASS	PASS	PASS	PASS	*FAIL*
8	31	LFAIL*	*FAILH	PASS	PASS	PASS	*FAIL*
9	31	LFAIL*	PASS	PASS	PASS	PASS	*FAIL*
10	31	PASS	PASS	PASS	PASS	PASS	PASS
11	30	LFAIL*	PASS	PASS	PASS	PASS	*FAIL*
12	29	PASS	PASS	PASS	PASS	PASS	PASS
13	28	LFAIL*	PASS	PASS	PASS	PASS	*FAIL*
14	25	PASS	*FAILH	PASS	PASS	PASS	*FAIL*
15	24	LFAIL*	*FAILH	PASS	PASS	PASS	*FAIL*
16	11	NOTEST	NOTEST	PASS	PASS	PASS	PASS

Table 6: Summary report for station 72456
10/01/90 to 10/31/90 at 00Z

Appendix: Program listing

```

C      THIS PROGRAM IS FOR CHECKING THE STANDARD FORECAST DEVIATION
C      FILES FOR OUTLIERS IN: (1) DAILY READINGS, (2) MEANS, AND
C      (3) STANDARD DEVIATIONS OF STATIONS WITHIN A TARGET DISTANCE
C      OF A GIVEN LATITUDE AND LONGITUDE.
C
C      WRITTEN BY RICHARD FRANKE
C              DEPARTMENT OF MATHEMATICS
C              NAVAL POSTGRADUATE SCHOOL
C              MONTEREY, CA 93943
C              0083P@CC.NPS.NAVY.MIL
C              408/646-2758
C
C      DATE OF BEGINNING: 6/21/91
C      DATES OF CHANGES: 6/21/91
C      MODIFIED TO USE SYMBOLS FOR OUTPUT: 6/21/91
C      MINOR PRETTYING UP: 6/24/91
C      MODIFIED TO NOTE NUMBER OF TESTS AND SUMMARY BY STATION: 6/27/911
C
C      PARAMETER (MX=152,NS=15)
C      REAL FE(MX,NS,16),FER(MX,NS),XMN(NS),STD(NS),FED(NS)
C      INTEGER YRMD(MX,NS),NSTAT(NS),KNT(NS),NSD(NS),
1      NDLF(NS,16),NDHF(NS,16),NSDF(NS,16),NMNLF(NS,16),NMNHF(NS,16),
2      NSS(NS),YMD(MX,NS),NDG(NS,16),NDDT(NS,16),LATS(NS),LONS(NS)
C      CHARACTER*15 IUNIT,OUNIT
C      CHARACTER*6 FLAGS(-1:1),FLAGSL(-1:1),FLAGSH(-1:1)
C      CHARACTER*1 SY(-1:36)
C      CHARACTER*38 SY
C      EQUIVALENCE (SY,SY)
C      DATA SY/'*.123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ&'/
C      DATA FLAGS/'NOTEST',' PASS ','*FAIL*'/,
1      FLAGSL/'NOTEST',' PASS ','LFAIL*'/,
2      FLAGSH/'NOTEST',' PASS ','*FAILH'/
C
C      GET DATA INPUT FILE NAME AND OUTPUT FILE NAME
C
C      WRITE(*,9)
9      FORMAT(' NAME THE INPUT FILE')
C      READ(*,10)IUNIT
10     FORMAT(A15)
C      OPEN(4,BLANK='ZERO',FILE=IUNIT,MODE='READ',STATUS='OLD')
C      WRITE(*,21)
21     FORMAT(' NAME THE OUTPUT FILE')
C      READ(*,10)OUNIT
C      OPEN(8,FILE=OUNIT,MODE='WRITE',STATUS='NEW')
C
C      GET THE INPUT
C
100    WRITE(*,1)
1      FORMAT(' INPUT THE TARGET LATITUDE, LONGITUDE AND THE RANGE',/
1      ' - FREE FIELD - RANGE = 0 STOPS EXECUTION',/)
C      READ(*,*)LAT,LON,LLR
C      IF(LLR.LE.0)STOP

```

```

C
C      STRETCH OUT IN THE LONGITUDINAL DIRECTION
C
C      LTR=LLR/COS(FLOAT(LAT)/57.3)
C
C      START INPUT UNIT 4 AT THE BEGINNING
C
C      REWIND 4
C      MS = 0
C
C      READ A HEADER
C
200  READ(4,2,END=300)NST,ILAT,ILON,ITM,NREC
    2  FORMAT(BZ,3X,I7,4X,2I5,8X,I2,I5)
      IF(ABS(ILAT-LAT).LE.LLR .AND. ABS(ILON-LON).LE.LTR) THEN
C
C          IT'S IN THE RECTANGLE, GET THE DATA
C
C          MS=MS + 1
C          NSTAT(MS)=NST
C          LATS(MS)=ILAT
C          LONS(MS)=ILON
C          READ(4,3)((FE(I,MS,J),J=1,16),YRMD(I,MS),I=1,NREC)
    3  FORMAT(BZ,16F4.0,I8)
      ELSE
C
C          OR SKIP IT
C
C          READ(4,4)(JUNK,I=1,NREC)
C          ENDIF
    4  FORMAT(I1)
C
C      GO BACK FOR MORE IF WE DON'T HAVE THE MAX
C
C      IF(MS.LT.NS) GO TO 200
C      PRINT 7
    7  FORMAT(' STOPPING BEFORE END')
300  CONTINUE
      IF(MS.LT.4) THEN
C          WRITE(*,5)MS
C
C          NOT ENOUGH DATA, START OVER
C
    5  FORMAT(' ONLY',I2,' STATIONS FOUND - START OVER')
      GO TO 100
      ELSE
C          WRITE(*,6)MS,(NSTAT(N),N=1,MS)
    6  FORMAT(15,' STATIONS FOUND:',/(I10))
      ENDIF
C
C      GET THE DATE RANGE
C
301  WRITE(*,8)

```

```

8  FORMAT(' INPUT THE BEGINNING AND ENDING DAYS (>=1, <=152)'/
1      ' BEGINNING = ZERO GOES TO NEW LATITUDE/LONGITUDE'/
2      ' BEGINNING = NEGATIVE ENDS RUN')
READ(*,*)IDB,IDE
IF(IDB.LT.0)STOP
IF(IDB.EQ.0)GO TO 100

C
C  OK, LET'S DO THE JOB
C
C  ZERO OUT FLAG FIELDS
C
DO 304 L=1,16
  DO 303 N=1,NS
    NDLF(N,L) = 0
    NDHF(N,L) = 0
    NSDF(N,L) = -1
    NMNLF(N,L) = -1
    NMNHF(N,L) = -1
    NDG(N,L) = 0
    NDDT(N,L) = 0
303  CONTINUE
304  CONTINUE

C
C  LOOP OVER ALL LEVELS
C
DO 400 L=1,16
  KS=0

C
C  KS COUNTS STATIONS WITH A HISTORY OF 2 OR MORE DAYS
C
DO 305 N=1,MS
  KNT(N) = 0
  XMN(N) = 0.

C
C  KNT COUNTS HOW MANY DAYS
C
305  CONTINUE
DO 310 I=IDB,IDE
  ND=0
  DO 308 N=1,MS

C
C  ND COUNTS THE NUMBER OF STATIONS WITH GOOD DATA TODAY
C  FED SAVES IT FOR THE TEST
C  NSD TELLS WHICH STATIONS HAVE GOOD DATA
C  FER SAVES IT ALL FOR MEAN AND STD CALCS
C  YRMD SAVES THE DATE INFORMATION (NOT USED PRESENTLY, 6/21
C
  FED(N)=0.
  IF(FE(I,N,L).LT.999) THEN
    NDG(N,L)=NDG(N,L)+1
    KNT(N) = KNT(N) + 1
    ND=ND+1
    FED(ND)=FE(I,N,L)
    NSD(ND)=N

```

```

        FER(KNT(N),N) = FE(I,N,L)
        YMD(KNT(N),N) = YRMD(I,N)
        XMN(N)=XMN(N)+FER(KNT(N),N)
    ENDIF
308    CONTINUE
C
C    TEST CURRENT DAY'S DATA
C
    CALL R11P05(FED,ND,NB,IB,NT,IT,IER)
    IF(IER.LE.0) THEN
        IF(NB.GT.0)NDLF(NSD(IB),L) = NDLF(NSD(IB),L) + 1
        IF(NT.GT.0)NDHF(NSD(IT),L) = NDHF(NSD(IT),L) + 1
        DO 309 N=1,ND
            NDDT(NSD(N),L) = NDDT(NSD(N),L) + 1
309    CONTINUE
        ENDIF
310    CONTINUE
    DO 315 N=1,MS
        IF(NDDT(N,L).EQ.0) THEN
            NDLF(N,L) = -1
            NDHF(N,L) = -1
        ENDIF
315    CONTINUE
    DO 330 N=1,MS
        IF(KNT(N).GT.1)THEN
C
C    CALCULATE MEAN AND ST. DEV IF MORE THAN ONE DAY OF DATA
C
            KS=KS+1
            NSS(KS) = N
            XMN(KS)=XMN(N)/KNT(N)
            S= 0.
            DO 320 I=1,KNT(N)
                S=S+(FER(I,N)-XMN(KS))**2
320    CONTINUE
            STD(KS) = SQRT(S/(KNT(N)-1))
            ENDIF
330    CONTINUE
C
C    RUN TEST ON MEAN VALUES FOR THE STATIONS
C
    CALL R11P05(XMN,KS,NB,IB,NT,IT,IER)
    IF(IER.EQ.0)THEN
        DO 340 N=1,KS
            NMNLF(NSS(N),L) = 0
            NMNHF(NSS(N),L) = 0
340    CONTINUE
            IF(NB.NE.0) NMNLF(NSS(IB),L)=1
            IF(NT.NE.0) NMNHF(NSS(IT),L)=1
        ENDIF
C
C    RUN TEST ON STANDARD DEVIATIONS OF THE STATIONS
C
    CALL R10P05(STD,KS,NT,IT,IER)

```



```

        IF( IER.EQ.0)THEN
            DO 360 N=1,KS
                NSDF(NSS(N),L) = 0
360         CONTINUE
                IF(NT.GT.0)NSDF(NSS(IT),L) = 1
            ENDIF
400        CONTINUE
        MDATEB=0
        MDATE=0
        DO 410 N=1,MS
            IF(MDATEB.EQ.0)MDATEB=YRMD( IDB,N)
            IF(MDATE.EQ.0)MDATE=YRMD( IDE,N)
410        CONTINUE
            IF(MDATEB.EQ.0)MDATEB=MDATE-( IDE-IDB)
            IF(MDATEB.LT.0)MDATEB=IDB
            IF(MDATE.EQ.0)MDATE=MDATEB+( IDE-IDB)

C
C
C        OUTPUT RESULTS FOR VARIOUS TESTS

        WRITE(8,11)MDATEB,MDATE,ITM,LAT,LON,LLR,LTR
11        FORMAT('1  RESULTS OF THE OUTLIER TESTS FROM',
1          I8,' TO',I8,' AT',I3,'Z'//
2          '    NUMBER OF FAILURES BY LEVEL AND STATION: .=0, *=NOTEST'
3          //'    TARGET LATITUDE/LONGITUDE IS',2I5,', RANGE:',I2,'X',I2
4          //'    RESULTS OF THE DAILY OUTLIER TEST (LOW FAIL/HIGH FAIL)')
        WRITE(8,12)((L),L=1,16)
12        FORMAT('/' STATION / Lvl',16I4/)
        WRITE(8,13)(NSTAT(N),
1          (SY(NDLF(N,L)),SY(NDHF(N,L)),L=1,16),N=1,MS)
13        FORMAT(I8,5X,32A2)
        WRITE(8,20)IDE-IDB+1
20        FORMAT('//'    NUMBER OF DAYS DAILY OUTLIER TEST WAS PERFORMED'
1          ' OUT OF',I4)
        WRITE(8,12)((L),L=1,16)
        WRITE(8,18)(NSTAT(N),(NDDT(N,L),L=1,16),N=1,MS)
18        FORMAT(I8,4X,16I4)
        WRITE(8,14)
14        FORMAT('//'    RESULTS OF THE MEANS OUTLIER TEST (LOW FAIL/HIGH'
1          ' FAIL)')
        WRITE(8,12)((L),L=1,16)
        WRITE(8,13)(NSTAT(N),
1          (SY(NMNLf(N,L)),SY(NMNHf(N,L)),L=1,16),N=1,MS)
        WRITE(8,15)
15        FORMAT('//'    RESULTS OF THE STANDARD DEVIATION OUTLIER TEST')
        WRITE(8,12)((L),L=1,16)
        WRITE(8,16)(NSTAT(N),(SY(NSDF(N,L)),L=1,16),N=1,MS)
16        FORMAT(I8,4X,16A4)
        WRITE(8,17)IDE-IDB+1
17        FORMAT('//'    NUMBER OF DAYS REPORTING OUT OF',I4)
        WRITE(8,12)((L),L=1,16)
        WRITE(8,18)(NSTAT(N),(NDG(N,L),L=1,16),N=1,MS)

C
C
C        OUTPUT SUMMARY BY STATION

```

```

        WRITE(8,22)
22    FORMAT(//' *****',
1'*****',
2 '// SUMMARY BY STATION FOLLOWS')
        DO 500 N=1,MS
            WRITE(8,23) NSTAT(N), LATS(N), LONS(N)
23    FORMAT(//' -----',
1'-----',
2    '/' STATION', I6, ':  LAT, LON = ', I4, ', ', I4,
3    '/' LEVEL #DAYS      DAILY TESTS      MEANS TESTS      ',
4    ' STD TESTS      TOTAL')
        DO 420 L=1,16

```

C
C
C
C
C
C
C

```

        SET CODES FOR TESTS:  -1 IS NOTEST, 0 IS PASS ALL, 1 IS FAIL
                                ONE OR MORE
        FOR THE TOTAL TEST, NOTEST MEANS NO TESTS PERFORMED,
                                PASS MEANS PASS ALL TESTS PERFORMED (IF ANY)
                                FAIL MEANS FAILED AT LEAST ONE

```

```

        NFL=MIN(NDLF(N,L),1)
        NFH=MIN(NDHF(N,L),1)
        NMFL=MIN(NMNLF(N,L),1)
        NMFH=MIN(NMNHF(N,L),1)
        NSF=MIN(NSDF(N,L),1)
        NTF=MAX(NFL,NFH,NMFL,NMFH,NSF)
        WRITE(8,24) L, NDG(N,L), FLAGSL(NFL), FLAGSH(NFH),
1    FLAGSL(NMFL), FLAGSH(NMFH), FLAGS(NSF), FLAGS(NTF)
420    CONTINUE
24    FORMAT(2I6,4X,A6,3X,A6,5X,A6,3X,A6,5X,A6,5X,A6)
500    CONTINUE
        WRITE(8,19)
19    FORMAT(//' *****',
1'*****'////////)
        GO TO 301
        END

```

```

SUBROUTINE R10P05(X,N,NOUTT,IT,IER)
PARAMETER (MAX=30)
DIMENSION X(N),SX(MAX),ISX(MAX)
DIMENSION CV(30)

```

C
C
C
C
C
C

THIS SUBROUTINE DOES THE R10 TEST FOR OUTLIERS AT THE .05 CRITICAL TEST LEVEL.

THE CV VALUES ARE THE CRITICAL VALUES FROM TABLE V.

```

DATA CV/2*0,.941,.765,.642,.560,.507,.468,.437,.412,.392,.376,
1 .361,.349,.338,.329,.320,.313,.306,.300,.295,.290,.285,.281,
2 .277,.273,.269,.266,.263,.260/

```

C
C
C
C
C

INPUT VALUES ARE: X - THE DATA TO BE TESTED
 N - NUMBER OF DATA POINTS

OUTPUT VALUES ARE: NOUTT - FLAG FOR LARGEST VALUE

```

C          0 IF OK, 1 IF NOT
C          IB      - LOCATION IN X ARRAY
C          IER     - ERROR RETURN INDICATOR
C          0 IF ALL OK
C          1 IF N OUT OF RANGE 4 TO MAX, INCLUSIV
C          NO TEST PERFORMED
C
C CHECK FOR SUITABLE N
C
C      IER = 0
C      NOUTT = 0
C      IF(N.LT.3.OR.N.GT.MAX)THEN
C          IER = 1
C          RETURN
C      ENDIF
C      DO 100 I=1,N
C          SX(I) = X(I)
C          ISX(I) = I
100 CONTINUE
C
C      SORT INTO INCREASING ORDER
C
C      CALL SHSORT(SX,ISX,N)
C      RT = 0.
C      IF(SX(N)-SX(1) .NE. 0.) RT = (SX(N) - SX(N-1))/(SX(N) - SX(1))
C      IF(RT.GT.CV(N))THEN
C          NOUTT = 1
C          IT = ISX(N)
C      ENDIF
C      RETURN
C      END
C
C      SUBROUTINE R11P05(X,N,NOUTB,IB,NOUTT,IT,IER)
C      DIMENSION X(N),SX(30),ISX(30)
C      DIMENSION CV(30)
C
C      THIS SUBROUTINE DOES THE R11 TEST FOR OUTLIERS AT THE .05 CRITICAL
C      TEST LEVEL.
C
C      THE CV VALUES ARE THE CRITICAL VALUES FROM TABLE V.
C
C      DATA CV/3*0,.955,.807,.689,.610,.554,.512,.477,.450,.428,.410,
1 .395,.381,.369,.359,.349,.341,.334,.327,.320,.314,.309,.304,
1 .299,.295,.291,.287,.283/
C
C      INPUT VALUES ARE:  X - THE DATA TO BE TESTED
C                          N - NUMBER OF DATA POINTS
C
C      OUTPUT VALUES ARE:  NOUTB - FLAG FOR SMALLEST VALUE
C                            0 IF OK, 1 IF NOT
C                            IB      - LOCATION IN X ARRAY
C                            NOUTT - FLAG FOR LARGEST VALUE
C                            0 IF OK, 1 IF NOT

```

```

C          IT    - LOCATION IN X ARRAY
C          IER    - ERROR RETURN INDICATOR
C                   0 IF ALL OK
C                   1 IF N OUT OF RANGE 5 TO 30, INCLUSIVE
C
C
C
C
C

```

```

C CHECK FOR SUITABLE N
C

```

```

C     IER = 0
C     IF(N.LT.4.OR.N.GT.30)THEN
C         IER = 1
C         RETURN
C     ENDIF
C     DO 100 I=1,N
C         SX(I) = X(I)
C         ISX(I) = I
100 CONTINUE
C

```

```

C SORT INTO INCREASING ORDER
C

```

```

C     CALL SHSORT(SX,ISX,N)
C     RB = 0.
C     IF(SX(N-1)-SX(1) .NE. 0.) RB = (SX(2) - SX(1))/(SX(N-1) - SX(1))
C     NOUTB = 0
C     IF(RB.GT.CV(N))THEN
C         NOUTB = 1
C         IB = ISX(1)
C     ENDIF
C     RT = 0.
C     IF(SX(N)-SX(2) .NE. 0.) RT = (SX(N) - SX(N-1))/(SX(N) - SX(2))
C     NOUTT = 0
C     IF(RT.GT.CV(N))THEN
C         NOUTT = 1
C         IT = ISX(N)
C     ENDIF
C     RETURN
C     END

```

```

C Included for completeness only - from NONIMSL library at NPS

```

```

C .....
C

```

A. IDENTIFICATION:

```

C     TITLE:      NUMERICAL SORT
C     ID:         M1-NPG-SHSORT (F-IV)
C     PROGRAMMER: R. BRUNELL
C     DATE:       MARCH 1968
C     MODIFIED:   DEC. 1973   BY L. NOLAN
C

```

B. PURPOSE:

```

C     TO SORT, IN ASCENDING ORDER, AN ARRAY OF SINGLE PRECISION REAL
C     NUMBERS BY THE METHOD OF SHELL, AND TO PRODUCE AN ARRAY OF INDEXES
C     SO USER CAN RE-ORDER OTHER CORRESPONDING INFORMATION ACCORDING TO

```

C ASCENDING VALUES OF "A".
C
C C. USAGE:
C 1. CALLING STATEMENT:
C CALL SHSORT(A,KEY,N)
C 2. ARGUMENTS:
C A - ARRAY OF NUMBERS TO BE SORTED. THIS ARRAY IS SORTED
C (RE-ORDERED) BY "SHSORT".
C KEY - ARRAY, DIMENSIONED AT LEAST N IN CALLING PROGRAM, TO BE
C FILLED BY USER WITH INTEGERS FROM 1 TO N. AFTER EXIT
C FROM SHSORT, KEY(1) WILL CONTAIN THE ORIGINAL INDEX OF
C THE SMALLEST ELEMENT OF "A"; KEY(2) WILL CONTAIN THE
C ORIGINAL INDEX OF THE NEXT-TO-SMALLEST ELEMENT OF "A";
C ETC. KEY(N) WILL CONTAIN THE ORIGINAL INDEX OF THE
C LARGEST ELEMENT OF "A".
C N - NUMBER OF MEMBERS IN ARRAYS "A" AND "KEY".
C
C D. REFERENCES:
C 1. "ALGORITHM 201, SHELLSORT", BOOTHROYD, J., "COMMUNICATIONS OF
C ACM", VOL 6, NO 8, AUGUST 1963, P.445.
C 2. "CERTIFICATION OF ALGORITHM 201", BATTY,M.A., "COMMUNICATIONS
C OF ACM", VOL 7, NO 6, JUNE 1964, P.349.
C

```

SUBROUTINE SHSORT(A,KEY,N)
  DIMENSION A(N),KEY(N)
  M1=1
6  M1=M1*2
   IF (M1 .LE. N) GO TO 6
   M1=M1/2-1
   MM=MAX0(M1/2,1)
   GO TO 21
20 MM=MM/2
   IF (MM .LE. 0) GO TO 100
21 K=N-MM
22 DO 1 J=1,K
   II=J
11 IM=II+MM
   IF (A(IM) .GE. A(II)) GO TO 1
   TEMP=A(II)
   IT=KEY(II)
   A(II)=A(IM)
   KEY(II)=KEY(IM)
   A(IM)=TEMP
   KEY(IM)=IT
   II=II-MM
   IF (II .GT. 0) GO TO 11
1  CONTINUE
   GO TO 20
100 RETURN
   END

```


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